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Innovative track access charges

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Abstract

A detailed and serious cost calculation is a precondition for a competitive offer of railway traffic services in future. This task does not only concern the Train Operating Companies (TOCs), but also the Infrastructure Managers (IMs) when transferring the infrastructure costs into track access charges. These charges are subject to discussions since they were foreseen in the European regulations back in the 1990-ies the first time. The principle, to charge the "cost that is directly incurred as a result of operating the train service", lead to numerous different interpretation throughout Europe. Beside the legislation, it is still the objective of the IM to calculate the costs for the single train. Averaged charges based on gross-tonne-kilometres are definitely no proper estimation.

It is essential to base the charge on three levels. The first level is the network-section or line. The costs of Railway's permanent way differ very much on the given boundary conditions. Curved, mountainous sections come up with costs that are very likely up to three times higher compared to straight sections. Averaging costs network-wide leads to unfair conditions. Modulating gross-tonne-based charges due to the line conditions is the first necessary attempt in order to calculate "directly incurred costs". A proper cost accounting system provides all necessary input data.

The second step has to be seen from the view of the competiveness of railway freight transport. Just allocating costs does not include the cost-by-cause principle. The infrastructure is designed and maintained to the highest needs of the collective of all users. One example is the quality of track geometry that generates much higher costs if only one train is operated on high speed. These high costs are distributed to all trains if simply allocating it to gross-tonnage. Turnouts are a second major cost driver. As only the cost level is given by the accounting system, this steps needs a modelling process. Calculating gross-tonne-costs on a defined quality level is possible using detailed cost analyses for different assets at different quality standards. This second step makes it possible to calculate a cost level for freight operation, not covering the additional costs of fast or regional passenger services, and is therefore a pre-condition for a competitive railway freight service in a tight market situation.

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Last but not least, the quality of rolling stock is an essential part of the generated infrastructure costs. The forces of the rail-wheel-contact define the wear and damage process on the track involving the maintenance cost to be charged. It needs a sound track deterioration model to calculate the cost relevance of different forces. This modulation is an important step towards lower overall costs of the total railway system, as optimisation of subsystems is eliminated.
In the end, Track Access Charges must be calculated on a much more detailed level in order to cover the goals defined by the cost-by-cause principle and a non-discriminatory access to railway infrastructure. Most of the necessary data are existing, it needs to transform the detailed cost calculation to a manageable charging system.

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1. Introduction

The liberalisation of the European Railway sector is based on the splitting of infrastructure and train operation. The overall goal of this process is defined clearly, in several documents and directives (European Community (1991), European Commission (2001), European Commission (2011), European Parliament and Council (2012)). Due to the competition of several railway undertakings (RUs, train operating companies TOCs) on the provided infrastructure the system costs should decrease. Due to that effect the transport mode Railway can compete also in the intermodal perspective. The infrastructure is generally provided by the member states, while infrastructure managers (IMs) organise traffic, allocate capacity and maintain the assets. One main aspect is thereby the independence of the IMs from any train operation company, so that train path allocation is guaranteed to be non-discriminatory. Directives specify also the financial situation of the IMs: the accounts must be balanced by state funding, track access charges and any other incomes. The charges are subject to a market regulation as in most cases the infrastructure managers are monopolists. There are many effects to be considered, when setting track access charges, amongst them the height of public infrastructure subsidies, the efficient use of the provided infrastructure, and the intermodal competiveness. Pricing needs to be non-discriminatory, fair and transparent to finally reach the goal of lower system costs. That means that charges have to be cost-based, wear-related, and demand-specific.

From the first directive on, the charges of the minimum access packages were meant to *"be set at the cost that is directly incurred as a result of operating the train service"* (European Parliament and Council (2012)). This definition let room for interpretation - too much room as it turned out: charges varied significantly throughout Europe. One major problem was, that most IMs did not point out, which part of the charge was the "cost directly incurred" and which part was a so-called "mark-up". The implementing act (European Commission (2015)), published in June 2015, lays down rules for the calculation of the direct costs. The minimum requirement due to this regulation is to divide the network wide direct costs by the number of train kilometres, gross-tonne kilometres or vehicle kilometres or a combination of those. Next to the definition of costs to be considered (the follow-up costs of wear and tear, basically) one question is important: which unit is proper? For track, it might be gross-tonnes kilometres, for the other costs probably the number of trains. The following evaluations are focused on track costs as these costs define the overwhelming part of the direct costs.

2. Track Costs – Cost based approach

Beside the fact that on low loaded lines track maintenance is not wear and tear related only, also on high loaded tracks maintenance costs vary significantly. The loading, on a gross-tonne level, might be a good estimation as long as other boundary conditions are equal. Figure 1 shows the result of a life cycle cost (LCC) evaluation based on Austrian data. Comparable evaluations in many other countries show equal results, on different cost levels of course.

It can be shown that maintenance costs (yellow bars in figure 1) rise with the number of gross-tonnes passing, in average. Parameters like mix of trains, train speed, or axle loads are not treated in these evaluations.

This indicates, that also a gross-tonne-kilometre based charging should be proper. This might be true, if track properties do not change significantly throughout the network. For a mixed traffic network, this is not the case. There are some relevant boundary conditions influencing the cost level to a high degree.

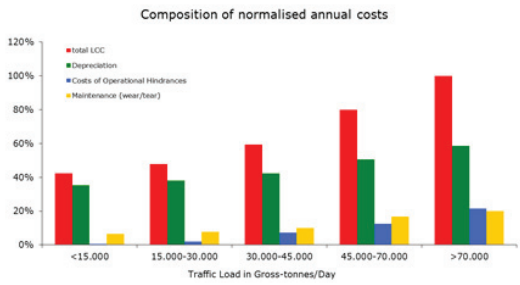

Fig. 1. Life cycle costs of track – gross-tonnage.

The most relevant properties are:

- Curve radius
- Substructure quality
- Superstructure used
- Turnouts
- Maintenance regime

2.1. The influence of the curve radius

If track radius decreases, the maintenance actions for the rails increase dramatically and track geometry corrections is much more frequently. In very narrow curves, the costs for changing the outer rails due to railhead side wear dominate the overall maintenance costs. Figure 2 shows this effect that leads to 16 times higher maintenance costs for jointed tracks in radii smaller than 250 metres compared to tangent tracks. Moreover, the maintenance costs thereby origin from very different wear processes. In curved track, rail maintenance is much higher due to rail contact fatigue on the surface and rail wear on the outer rail. Maintenance in curved track can be reduced by using higher steel grades for the rails and optimised track systems containing of modified rail pads, rail fastenings, elastic footings for concrete sleepers, and innovative sleeper design like HD-sleepers or frame sleepers. In any case, the lower maintenance is paid with higher (re-)investment costs.

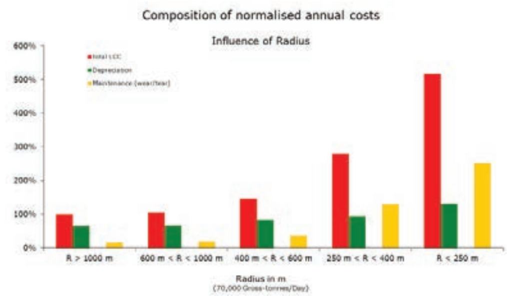

Fig. 2. Average maintenance costs – influence of radii.

2.2. The influence of substructure and superstructure

For many infrastructure managers the costs for re-establishing proper track geometry (tamping, ballast cleaning) is one of the highest cost proportion in track maintenance (Ekberg, A.; Paulsson, B. (2010)). Next to the ballast quality, the substructure is decisive for maintenance costs and service life of track. As figure 3 (a) shows, track maintenance increases to a seven times higher level, if quality of substructure is poor. Improvement is costly and economically feasible only with reinvestment of the track superstructure.

Also different types of superstructure lead to changes in track maintenance costs. For high loaded tracks differences between slab track and light superstructure ballasted track range up to a factor 7. Figure 3 (b) depicts average annual costs (depreciation and maintenance), but does not cover additional substructure costs for slab track. These evaluations are rather important for track optimisation than for track access charging as older superstructure is normally replaced in standard reinvestment procedure by newer (low maintenance) one. In an entire network lines show older tracks and newer ones, so that different superstructures (and different track ages) occur in a certain mix. Anyhow, slab tracks and tracks with under sleeper pads show significant lower maintenance costs. If these two superstructure types are in use, costs are on a much lower level. This is the case especially when it comes to new lines.

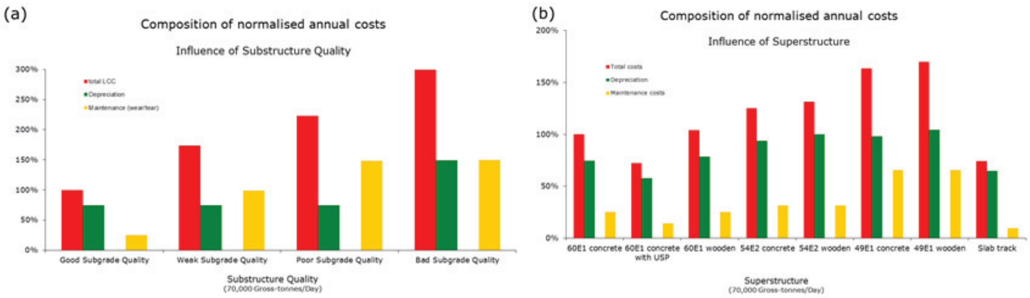

Fig. 3. Average maintenance costs – influence of substructure (a) and superstructure (b).

2.3. The influence of turnout – number and size

Within track, turnouts are the most costly assets. Per metre, this point infrastructure leads up to seven times higher maintenance costs (figure 4). That means a standard turnout with a diverging radius of 500 metres leads to the same maintenance costs than 500 metres of open track. Whenever analysing track maintenance costs of a line, the amount of turnouts is an important parameter. In mixed traffic networks, 0.9 turnouts per track kilometre is a good average for calculations. However, the amount of turnouts in a specific line segment can easily reach the triple value. For the total track maintenance costs of a line, additionally the size of the turnouts and their geometry have to be addressed.

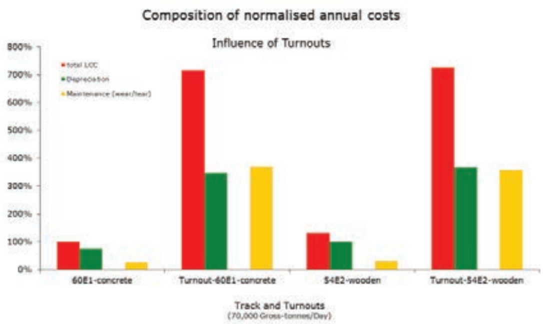

Fig. 4. Average maintenance costs – influence of turnouts.

2.4. The influence of the maintenance regime

A discussion or a benchmark of track maintenance costs is only possible if the general track maintenance regime is analysed. A LCC based sustainable strategy needs a certain amount of maintenance to ensure a high service life of track, and therefore a low depreciation. If the economically feasible service life is reached, track maintenance increases much faster than depreciation shrinks. Additionally to that, costs of slow orders (cost of operational hindrances) go up, resulting in higher total life cycle costs. Another strategy is to minimise maintenance – a common strategy whenever budgets are short. In the long-term perspective, service life cannot be reached leading to a high depreciation and an unbeneficial solution. Changing components whenever they are totally worn out is also (much) more expensive than a strategy with a total reinvestment at a certain point in time. This analysis turned out to be true for high loaded track in various countries with significantly different cost levels. Figure 5 shows these analyses.

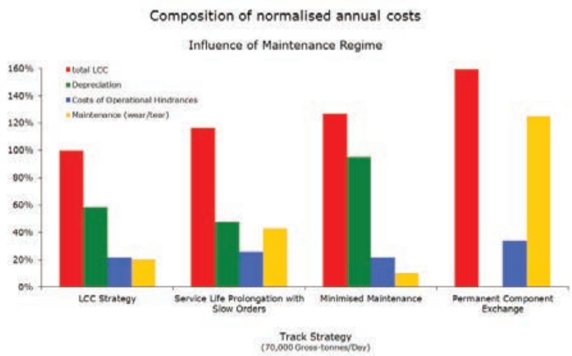

Fig. 5. Average maintenance costs – influence of different maintenance regimes.

Apart from the permanent component exchange philosophy, maintenance costs vary at least by a factor of 4. Shortage of maintenance budgets, as well as overaged tracks with their high maintenance costs and operational follow-up costs occur within one network, sometimes in single lines.

2.5. Summary track costs

When averaging maintenance costs of different lines throughout the network, using one parameter (gross-tonnage) only, a shifting of costs from one line to another occurs. Figure 6 shows some generic results: Costs are shifted from curvy lines to straight ones, from tracks with a high number of turnouts to those with a low turnout frequency, and from old lines to new ones. Depending on the line properties, gross-tonne-kilometre costs can vary significantly.

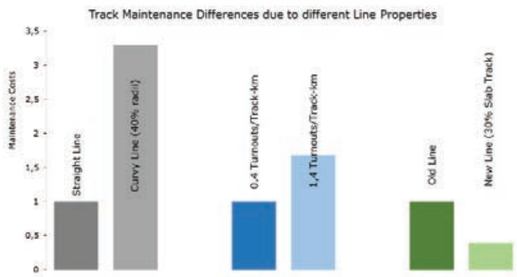

Fig. 6. Maintenance costs differences due to different line properties.

This might be a neglectable note, as long as only one railway undertaking operates trains on the entire network. If different RUs are involved, it is very likely that some of them operate their trains on parts of the network or even on one line only. In this case, the averaging of costs likely leads to unfair and discriminating charges. It must be guaranteed that the costs are allocated to the cost originator and this cannot be assured by an average gross-tonne-kilometre charge. Without having a close look on the transport volumes on the network, it is impossible to find out which RUs or market segments are disadvantaged. For proper track access charges a line specific charging is the minimum requirement to ensure the cost-by-cause principle. Up to now, lines or corridors are used to specify mark-ups only. Wear and tear costs of track are charged on a network-wide basis most commonly.

3. Track deterioration – Wear based approach

In chapter 2, track maintenance costs have been analysed from the track and line properties point of view. All presented cost differences are calculated still on an average level. Following the regulation 2015/909 (European Commission (2015)), it is up to the infrastructure manager (or member states authority) to define the unit the costs are referred to. From a net-wide average cost allocation to train-kilometres, gross-tonne-kilometres or vehicle-kilometres, it is allowed to modulate charges taking into account different aspects. Radii distribution and point infrastructure have been discussed already in the previous chapter. Vehicle characteristics, like static axle load, un-sprung masses, traction power, and bogie design, cannot be described using gross-tonne-kilometre approach (even though calculated charges for vehicle-kilometres can be re-calculated to a gross-tonne-kilometre level; see figures below). As un-sprung masses are only relevant for the dynamic axle load, speed must be covered as well.

As a first step towards this vehicle-based wear approach, the effect of different vehicle characteristics on track component wear/damage must be described. Tunna, J. et.al. (2008), Andersson, E.; Öberg, J (2007), and Holzfeind, J. et.al. (2015) published models, focussing on the mentioned vehicle parameters. For track maintenance costs in a sustainable track maintenance regime, a hybrid model of the Swiss wear formula and the Swedish approach turned out to fit best when it comes to cost recovery on different lines.

This approach defines the cost per vehicle-kilometre with

$$C_V = k_{1_{i,R}} \times \frac{T_V}{n} \times P_{2mod}{}^{3} + k_2 \times \frac{T_V}{n} \times P_{2mod}{}^{1,2} + k_3 \times \frac{T_V}{n} \times T_{pv} + k_{4_R} \times T_V \times W_b + k_5 \times \omega \times \frac{T_V}{n} \times \sqrt{\left(0.5 \times P_{2mod,40kmph}{}^{2} + 0.5 \times Y_{qs,R185m}{}^{2}\right)} \quad (1)$$

whereby

C_V	costs per vehicle kilometre
T_V	weight of the vehicle in tons
n_v	number of axles
P_{2mod}	the P2 force following the RGS with a reduced track failure (55%) depending on the speed
T_{pv}	Traction power value
W_b	damage-index calculated due to the Tγ model depending on the track radius
$P_{2mod,40kmph}$	modified P2 force at a speed of 40 kmph (run through a turnout radius of 185 metres)
$Y_{qs,R185m}$	quasi-static Y force in a turnout radius of 185 metres
k_{1R}	cost calibration factor referring to track tamping and small maintenance in through-going track depending on the track radius
k_2	cost calibration factor referring to rail grinding in straight through-going track (40%)
k_3	cost calibration factor referring to rail grinding in straight through-going track (60%)
k_{4R}	cost calibration factor referring to rail grinding, respectively rail exchange depending on the track radius
k_5	cost calibration factor referring to turnout component exchange (frog, tongue rail, guide rails) and small maintenance in turnouts
ω	factor for the amount of turnouts on a line-segment

This formula addresses the biggest cost portions of track maintenance costs and connects it to vehicle properties. This approach opens a wide field of further evaluations, not only proper track access charging. Analysing track behaviour or better specific component wear or damage, the impact of vehicle properties instead of gross-tonnes will help in future to find more detailed answers. In terms of track access charging this approach solves three major topics:

- The costs are allocated properly to the users. The impact of the dynamic axle load for example describes the cost causation much better than the vehicle weight. Other effects are simply not covered by the gross-tonne based charging, especially the transmitted traction power or the lateral force-level in curves and turnouts. Figure 7 shows how these parameters influence the track costs per vehicle-kilometre. In order to compare the given examples with the existing situation (average gross-tonne-kilometre charging, green bar in figures 8ff.), the track costs elaborated with the TDM are re-calculated on gross-tonne-level (yellow bars).

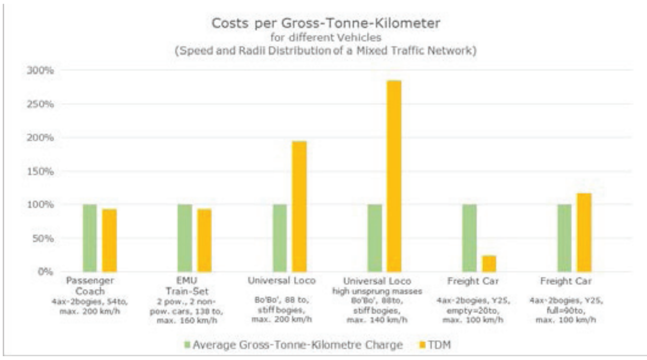

Fig. 7. Costs per gross-tonne-kilometre for different vehicles.

Looking at the results, the high charges for locomotives dominate figure 8. The combination of high axle load and un-sprung mass, high speeds, hauled axles, and rather stiff bogies lead to that result. On the other hand, the TDM allocates much less costs to empty freight wagons, defining the opposite of locomotives: low axle loads, low speeds.

- The track deterioration model makes it possible to include major cost relevant properties of the infrastructure: the model directly addresses the radius. The turnout frequency can be described by the factor ω. And finally, extraordinary track superstructure or substructure (e.g. slab track or new ballasted track with asphalt layers and/or concrete sleepers with under sleeper pads) can be handled by varying the k_1 cost calibration factor. In addition to that, the speed is included, adding one of the biggest cost drivers to the evaluation. Figure 8 shows for one example how different speeds and radii influence the track costs figures. Again, the track cost per vehicle-kilometre are re-calculate to gross-tonne-kilometre level.

Fig. 8. Costs per gross-tonne-kilometre for different speed levels and radii.

- Next to these cost allocation topics, there is one major improvement: the usage of a track deterioration model results in varying prices for different vehicles, but also for vehicle of the same type with different vehicle concepts. This provides an incentive for a more cost efficient use of the infrastructure. Figure 9 depicts the cost impact of increased un-sprung masses, weight, and bogie stiffness for the standard operation of a passenger loco (yellow bars). In the existing pricing schemes the higher weight is the only vehicle property that leads to (low) changes (green bars).

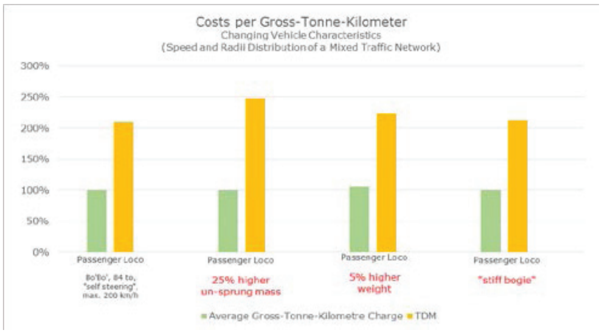

Fig. 9. Costs per gross-tonne-kilometre for changing vehicle properties

Of course, such an approach is more complex than the simply gross-tonne based one. It needs data on the vehicles in a train, on their loading and on vehicle properties. Additionally to that, it must be known on which speed and line (radii distribution, turnout frequency, etc.) the vehicles are operated. Most of this data is relatively easy to generate from available information.

4. Track configuration and quality – Demand based approach

The described approaches so far treated a proper cost allocation. This must be the first goal, taking the marginal cost definition due to the regulation 2015/909 (European Commission (2015)) seriously. Anyhow, the approaches discussed up to now only allocate the existing cost to the users in a proper way. This does not include the question whether the assets delivering these costs are needed by all the users. The demand of different TOCs, or better different market segments, in terms of track can be summarised to two aspects:

- Higher speeds demand for a higher preciseness of vertical track geometry. This quality demand automatically leads to higher costs due to more frequent tamping actions.
- Passenger services demand for a higher amount of turnouts. Regional trains need to stop more often. To reach the station tracks, turnouts are needed. Long distance passenger trains need a close crossover distance to keep delays low, whenever operational disturbances occur. In addition to that, turnouts for passenger services are designed for higher speeds too. Diverging radii of 500 m or 1,200 m, or even higher are definitely not installed for freight trains. These longer turnouts necessarily lead to higher costs.

Summarising these effects, a passenger traffic gross-tonne-kilometre is around 15% more costly than at freight traffic. Implementing these evaluations is possible in a gross-tonne-kilometre based charges as well as modifying TDM with these effects.

The TDM described in formula 1 indirectly covers different costs for different speed levels. The dynamic vertical impact is calculated with a constant track failure – a model approach that does not picture the reality in detail. Axles operated on high speeds are only run on high quality tracks, means on tracks with only small geometry failures. On the other hand, the cost calibration factor k_1 is a constant value, which is also not correctly. These two effects neutralise each other.

The differing turnout demand can be covered within the factor ω. It is important to say, that the modification only chages the allocation of the turnout costs, but not the absolute height of those.

5. Innovative Track Access Charges

Summarising the described approaches, track access charges for the track cost part (but not only for this) must fulfil three criteria. TACs must be

- cost based – allocating the costs, where they are generated
- wear based – allocating the costs to the originator (cost-by-cause principle)
- demand based – allocating the costs due to the user's needs

What seems to be much too complex for a pricing scheme, IT-based tools can handle easily. UK is already pricing with a basic version of a wear approach, Switzerland will introduce such wear-based charges in 2017 on a much higher, but still net-wide averaged level.

Innovative track access charges must ensure that they are transparently calculated and allocated as good as possible due to the existing knowledge. Only charges fulfilling the three outlined criteria avoid any discrimination. Three major aspects should be kept in mind, when future charging schemes are set up:

1. Assessability of the charges

The new regulative foresees a much more powerful role of the regulatory bodies than up to now. The regulators shall assess the IMs charging schemes and guarantee the charging principles defined in the EC regulations. As long as average gross-tonne-kilometre charges are levied RUs operating on selected lines only will have to accept cross financing other train operations in the network – a situation that is of course unacceptable. That will lead to a dangerous situation for the infrastructure managers. If the billed charges are higher than the actual costs (see the "Main line new" case in figure 10), the regulators will have to lower the level of charges if it comes to a case. Due to the averaging, the IMs cannot achieve cost recovery of the direct costs. The TDM based model provides the possibility to recover the costs line-specific (figure 10) and therefore prevents such situations.

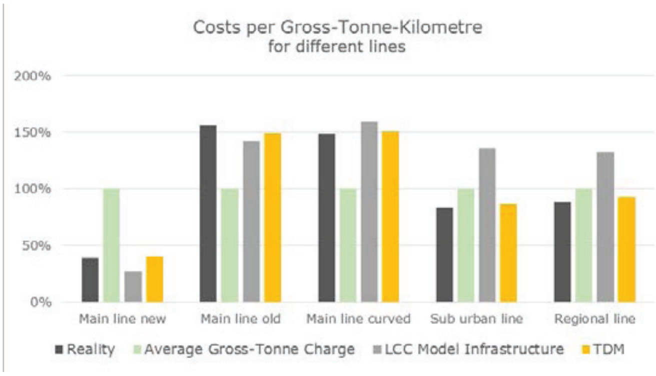

Fig. 10. Costs per gross-tonne-kilometre in reality and calculated with different approaches

2. Incentives for innovative track-friendly vehicle concepts

Gross-tonne-kilometre based charges do not punish excessive-wear vehicle construction. The only aspect for a RU to keep attention to is therefore the vehicle weight. Improved or innovative vehicle concepts with low un-sprung masses or self- /active-steering bogies cannot compete with low-cost designs, as the infrastructure savings due to less wear are not transposed to the vehicle holder. The savings on the RU's side due to reduced vehicle maintenance are too low to justify higher investment costs in most cases. This turns out to be a vicious cycle: low vehicle quality leads to increased track costs (per gross-tonne). That consequently means that track access charges go up. The cost for operating trains are therefore increased, and RUs are forced to save money on the vehicle side. This is counter acting the approach of the European railway policy that an inter-modal competition on a provided infrastructure leads to lower system costs in the long term.

3. Easing the financial burden of freight traffic

Both, the TDM and the demand approach point out the freight traffic is overpriced in the gross-tonne-kilometre based charging. Especially in railway freight transport the revenues are low (passenger traffic is subsidised or public-ordered in a big scale). To enhance the modal split of rail freight transport, the costs of the infrastructure use must be allocated in a fair way. As long as freight trains have to pay for infrastructure assets they simply do not need, a shift of traffic from road to rail is at least not supported.

6. Summary

Future's track access charges must be line-specific and vehicle-specific to be in line with the goals of European transport policy. The effects shown on the track part of direct costs are basically true also for the costs of catenary and civil engineering structures. There are already infrastructure managers making partly use of these ideas – hopefully others will follow. The Railway sector raised the proper allocation of infrastructure costs as one major question in the Roll2Rail project within the set-up of a universal cost model (Roll2Rail Consortium, 2015).

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